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WO 94/25732 A1
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FR 002723141 A
US 4821564 A

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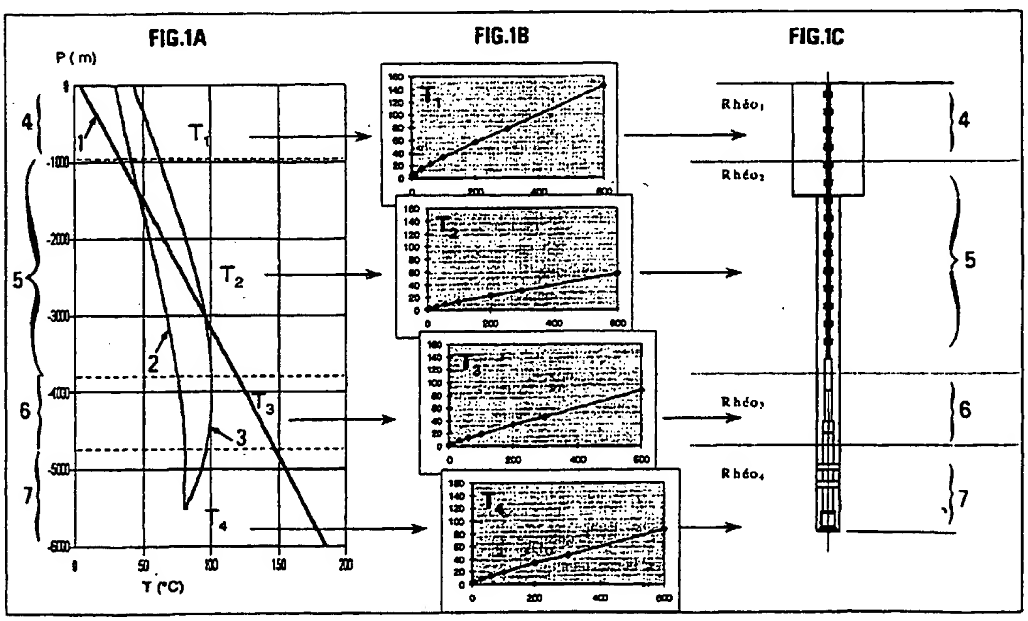
(54) Abstract Title
Fluid circuit pressure drop calculation

(57) A method or system for calculating pressure drops created by a fluid in a circuit having a determined thermal profile comprises a rheological database of fluids according to temperature, segmenting the thermal profile 2 and 3 and determining representative values of temperature T1, T2, T3 and T4 for each section 4, 5, 6 and 7, determining rheology of fluid at said temperature from database and calculating and adding up the pressure drops in each section. The thermal profile may be segmented for a constant temperature range. The representative temperature may be the mean. The rheology database may be according to pressure and may be organised into fluid families including laws governing variation of the rheology.



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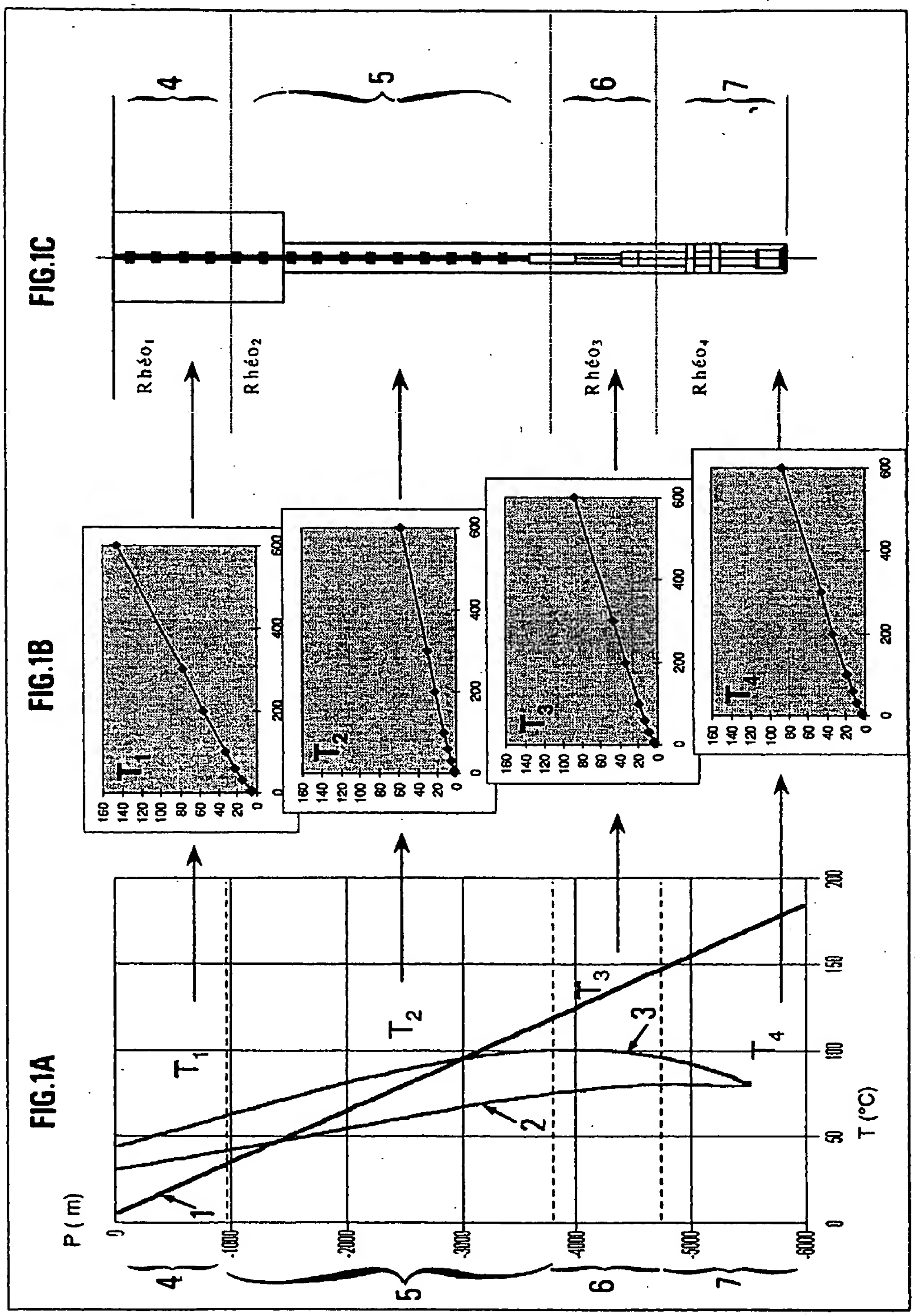


FIG.1A
FIG.1B
FIG.1C
P (m)
T (°C)
T1
T2
T3
T4
Rhéo1
Rhéo2
Rhéo3
Rhéo4
1
2
3
4
5
6
7

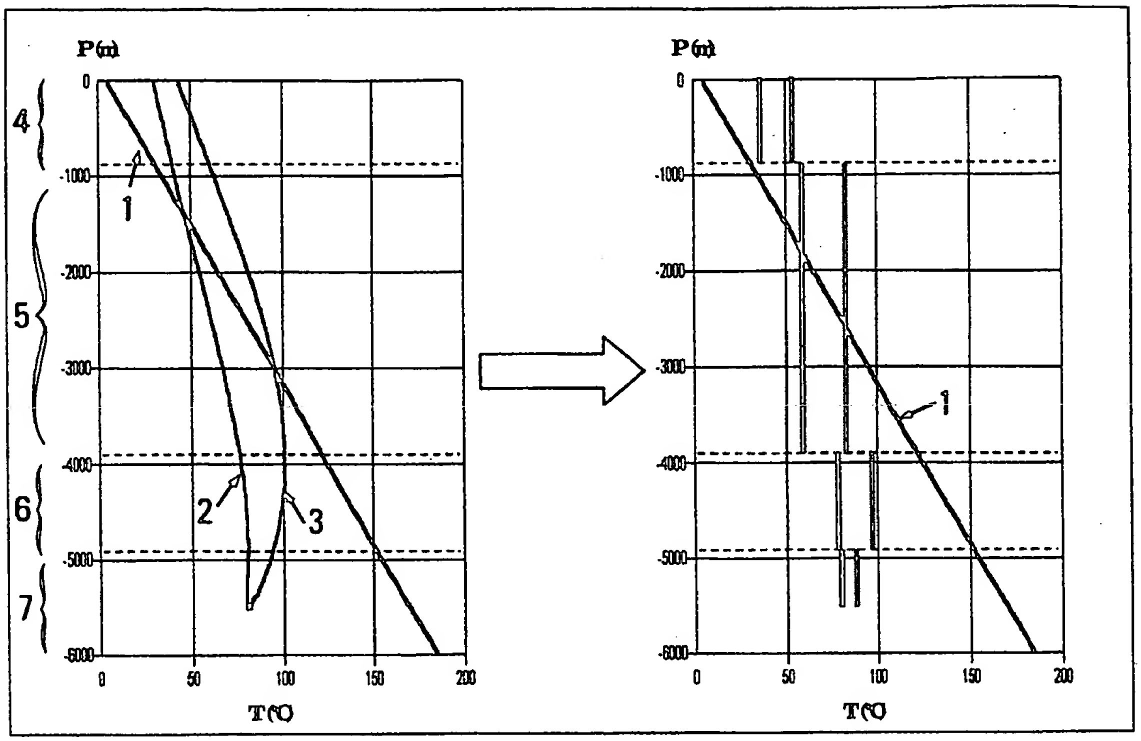


Figure 2a

Figure 2b

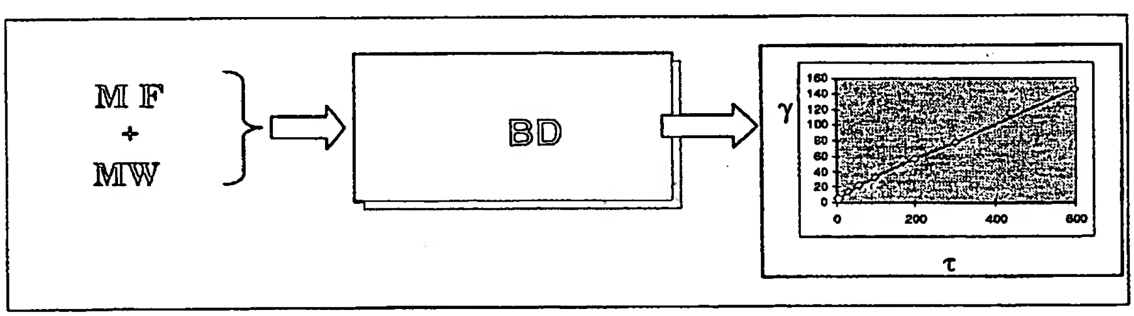


Figure 3

FIG.4

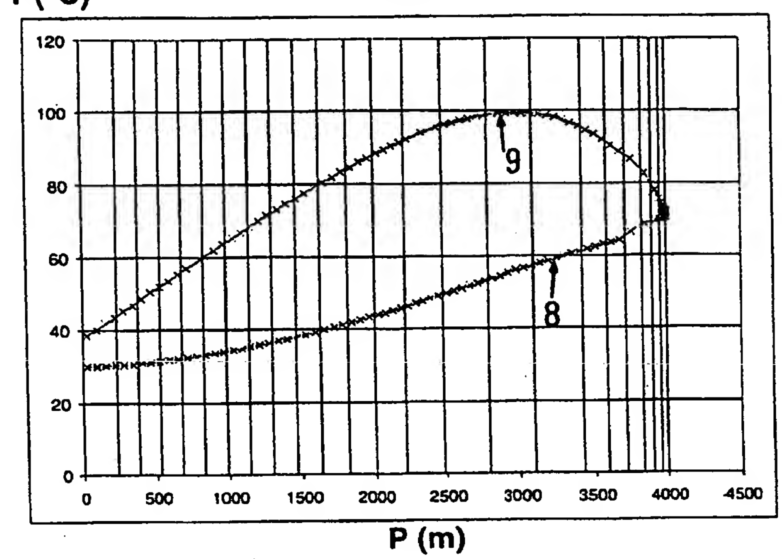
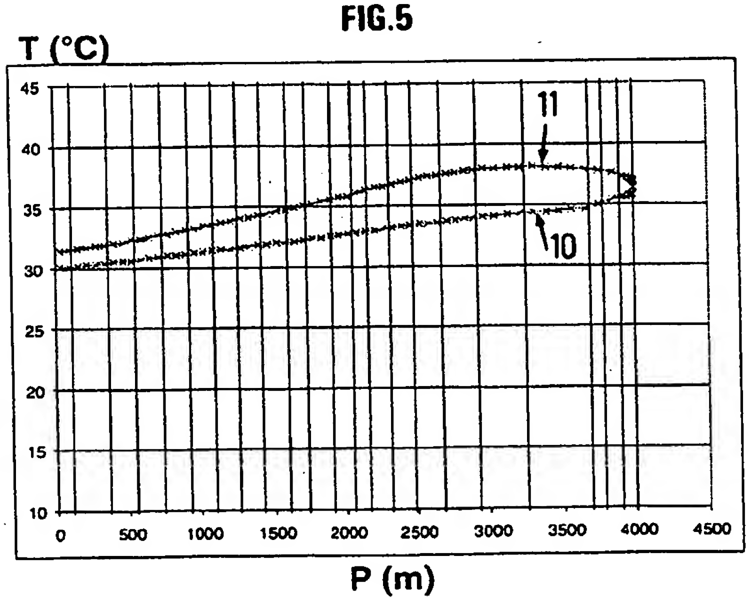

T (°C)
120
100
80
60
40
20
0
0
500
1000
1500
2000
2500
3000
3500
4000
4500
P (m)
9
8

FIG.5


T (°C)
45
40
35
30
25
20
15
10
0
500
1000
1500
2000
2500
3000
3500
4000
4500
P (m)
11
10

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PRESSURE DROP CALCULATION METHOD AND SYSTEM TAKING ACCOUNT OF THERMAL EFFECTS

The present invention relates to a method and to a system for calculating pressure drops in a circuit by taking account of the thermal effects along the circuit.

BACKGROUND OF THE INVENTION

Document US-5,850,621 describes a computer method allowing to calculate pressure drops in the various parts of a circuit consisting for example of : a well drilled in the ground, the inner space of drillpipes or of tubes in the well, the annular space between these pipes or tubes and the well wall. Known pressure drop calculation methods take account of the data relative to the well pattern, the characteristics of the circulating fluid and the flow conditions. In most calculation models, a rheology that is more or less representative of that of the fluid is taken into account : Bingham, Ostwald or other models. Some also take account of the influence of the rotation of the pipes and/or of the eccentricity in the well. However, these calculation models do not take account of the influence of the temperature variation and/or of the pressure variation on the rheology of the fluid, a relatively important parameter for pressure drop calculation. Now, the temperature and pressure conditions in a wellbore, offshore or onshore, are excessively variable, which currently leads to miscalculations.

SUMMARY OF THE INVENTION

The present invention thus relates to a method of calculating pressure drops created by a fluid in a circuit having a determined thermal profile. The following stages are carried out :

- making up a database giving the rheology of various fluids at least according to the temperature,

- segmenting the thermal profile into sections and determining a temperature value representative of that of the fluid in the section,

- using the database for determining the rheology of the fluid in each section at said representative temperature,

- calculating and adding up the pressure drops in each section considering the rheology determined.

The thermal profile can be segmented for a substantially constant temperature range.

The mean temperature of the fluid in each section can be taken as the representative temperature.

The database can comprise the rheology of fluids according to the pressure.

The mean pressure of the fluid in each section can be taken into account for determining the rheology of the fluid in said section.

The database can be organized in fluid families.

The database can comprise laws relative to the rheology variation according to the temperature and/or the pressure for each fluid family.

The invention also relates to a system for calculating pressure drops in a circuit by implementing the method described above, the system comprising means for segmenting the thermal profile along the circuit, means for managing a database giving

the rheology of various fluids according to the temperature and/or the pressure, means for calculating pressure drops in each section.

The method is advantageously applied to calculation of pressure drops in a well in the process of being drilled.

The present method is implemented for taking account of the influence, notably, of thermal effects on the pressure drop through the rheology of the fluid. The evolution of the temperature and of the pressure in the well locally modifies the viscosity of the mud and therefore the pressure drops generated. The precision of interpretation of the value and of the variations of the discharge pressure measured at the surface is greatly improved.

BRIEF DESCRIPTION OF THE DRAWINGS

Other features and advantages of the present invention will be clear from reading the description hereafter of non limitative examples, with reference to the accompanying drawings wherein :

- Figures 1A, 1B and 1C illustrate the principle of the present invention,
- Figures 2a and 2b show more precisely the segmenting procedure,
- Figure 3 diagrammatically shows coupling with a database,
- Figure 4 shows an example of a thermal profile in an onshore well used for dealing with an example,
- Figure 5 shows an example of a thermal profile in an offshore well.

DETAILED DESCRIPTION

The representations of Figures 1A, B and C sum up the principle of the method. Figure 1A gives the profile of the temperature (T in °C) as a function of the depth (P in metre). Curve 1 gives the geostatic temperature. From this local datum and from the thermal exchange parameters in the well (λ steel, formation, fluid ; fluid flow rate ; geometry, etc.), the profile of the temperature within the pipes (curve 2) and outside (curve 3) is determined by means of a thermal model. The « WELLCAT » (registered trademark) software marketed by the ENERTECH company (USA) can for example be mentioned here, which allows to determine this type of thermal profile in a well in the process of being drilled. The thermal profile is here segmented into sections 4, 5, 6, 7 according to the depth. Four sections whose representative temperatures are respectively T1, T2, T3 and T4 are shown here.

Figure 1B symbolically shows a database relative to the rheology of the fluid circulating in the well. A rheogram that is included in the base is associated with each temperature T1, T2, T3 and T4.

Figure 1C diagrammatically shows the cross-section of the well and the various circuit sections 4, 5, 6 and 7 to which the determined rheograms correspond.

Figures 2a and 2b describe more precisely the method for segmenting the thermal profile. Figure 2a is similar to the representation of Figure 1A and it shows the segmentation in four sections for which the mean temperature of each section has been selected as the representative temperature for the section considered. Figure 2a is transformed into the representation of Figure 2b where, in each section, the temperature is considered to be constant and equal to the mean temperature in this part.

Division into sections can be done automatically. It preferably is an even division as for the temperature but not for the length. The thermal profile can be segmented every 3°C for example, or more precisely, every 0.5°C. Thus, the temperature amplitude is the same in each section. The user can select the segmentation interval according to circumstances.

The temperature and the pressure in each section allow to determine the corresponding rheology by means of the mud database. By first approximation, the mean hydrostatic pressure can be selected for each section determined by the temperature range selected. The effect of the temperature is generally preponderant in relation to the pressure concerning the rheology variation of the drilling fluid.

The pressure drop is then calculated for each section, with the rheology determined for each section, prior to being summed up in order to obtain the total pressure drop in the circuit.

Figure 3 diagrammatically shows the calculation and the determination of the rheology with database BD. The database has been made up from families of drilling fluids (MF) used in the field. It comprises water-base muds and oil-base muds. Experimental measurements were carried out for temperatures ranging between 20°C and 170°C, pressure variations up to 400 bars and variable mud weights (MW). A rheometer Fann 70 (HP-HT) is conventionally used for the measurements allowing the rheograms to be drawn.

From knowledge of the fluid family to which the drilling fluid (MF) considered belongs and of the mud weight (MW), the corresponding existing rheological data are sought in base BD. It is possible to determine laws giving the rheology variation per

fluid family or subfamily according to the mud weight, pressure or temperature parameter. The existence of such laws simplifies calculations in the pressure drop calculation module.

The pressure drops can thus be calculated by means of a fluid rheology that is close to reality. Calculation can be fined down by means of the pressure value. In fact, if a simplified pressure value has been initially taken, for example the mean hydrostatic pressure of the section, the calculation model can recalculate the mean pressure more precisely by taking account of the static and dynamic pressure, which will be taken into account for the search in the database.

It is clear that segmentation of the thermal profile as described above can be done independently between the inner circuit and the annular circuit. The invention is not limited to a division into identical sections of equal depth for the inner pipe circuit and the annular circuit.

Example

A 4000-m deep onshore test well is simulated in a thermal calculation software allowing to obtain the temperature profile after a half-hour's drilling, from the equilibrium of the temperature of the fluid with the temperature of the formation. Figure 4 gives this temperature profile T in °C as a function of the depth in metre (abscissa). Curve 8 gives the temperature of the fluid in the pipes as a function of the depth. Curve 9 gives the temperature of the fluid in the annulus.

The circuit consists here of :

- a hole cased with a 13 "3/8 casing (inside diameter : 323 mm), 3000 m long,

- a hole 12.25 inches (311.15 mm) in diameter, 1000 metres long,
- 5" Grade G pipes, 3820 m long,
- 8" drill collars (OD=203.2 mm ; ID = 72 mm), 180 m long.

If the sum of the pressure drops Δp is calculated without taking account of the thermal effects (i.e. at a constant temperature equal to the surface temperature), in the case of a water-base mud and of an oil-base mud, the following results are obtained :

Bentonite water-base mud F1 : Δp=133.5 bars

Oil-base mud O1 : Δp=223.5 bars.

Considering the thermal profile segmented into 23 sections with a 4°C amplitude (it has been checked that the results are identical after 23 sections) and the use of the database relative to the rheology for the temperature and the pressure (mean hydrostatic pressure in the section considered), the results are as follows :

Bentonite water-base mud F1 : Δp=128.7 bars (difference : 4.8 bars ≈ **4 %**)

Oil-base mud O1 : Δp=195.8 bars (difference : 27.7 bars ≈ **12 %**).

A 4000-m deep offshore test well is simulated in a thermal calculation software allowing to obtain the temperature profile after 5 hours' drilling, from the equilibrium of the temperature of the fluid with the temperature of the formation. Figure 5 gives this temperature profile T in °C as a function of the depth in metre (abscissa). Curves 10 and 11 give the temperature of the fluid as a function of the depth respectively inside the pipes and in the annulus. The effect of the cooling of the drilling riser through a 2000-m water depth is very noticeable. The circuit given in this example is exactly the same as

the circuit of the previous example, except that there is a 2000-m water depth, the borehole being then only 2000 m long.

Considering the thermal profile segmented into 23 sections with a 0.5°C amplitude, the results obtained are as follows :

Bentonite water-base mud F1 : Δp=131.3 bars (difference : 2.2 bars ≈ **1.5 %**)

Oil-base mud O1 : Δp=216.2 bars (difference : 7.3 bars ≈ **3.5 %**).

The differences are lesser in this example because the temperature variation is much lower.

These examples show that the thermal and pressure effects that modify the rheology of the circulating fluid correspond in some critical cases to about 5 to 10 % of the sum of the pressure drops. The present invention notably allows to improve the calculation precision, which can admit of relevant comparisons between the calculated value and the measured value of the discharge pressure.

CLAIMS

1) A method of calculating pressure drops created by a fluid in a circuit having a determined thermal profile, characterized in that the following stages are carried out :

- making up a database (BD) giving the rheology of various fluids at least according to the temperature,
- segmenting said thermal profile (2, 3) into sections (4, 5, 6, 7) and determining a temperature value (T1, T2, T3, T4) representative of that of the fluid in said section,
- using the database for determining the rheology of the fluid in each section at said representative temperature,
- calculating and adding up the pressure drops in each section considering the rheology determined.

2) A method as claimed in claim 1, wherein the thermal profile is segmented for a substantially constant temperature range.

3) A method as claimed in claim 1 or 2, wherein the mean temperature of the fluid in each section is taken as the representative temperature.

4) A method as claimed in any one of the previous claims, wherein said database comprises the rheology of fluids according to the pressure.

5) A method as claimed in claim 4, wherein the mean pressure of the fluid in each section is taken into account for determining the rheology of the fluid in said section.

6) A method as claimed in any one of the previous claims, wherein said database is organized into fluid families.

7) A method as claimed in claim 6, wherein the database comprises laws relative to the variation of the rheology according to the temperature and/or to the pressure for each fluid family.

8) A system for calculating pressure drops in a circuit, comprising means for segmenting the thermal profile along the circuit, means for managing a database giving the rheology of various fluids according to the temperature and/or to the pressure, means for calculating the pressure drops in each section, characterized in that it implements the method as claimed in any one of claims 1 to 7.

9) Application of the method as claimed in any one of claims 1 to 7 to the calculation of pressure drops in a well in the process of being drilled.

10) A method substantially as hereinbefore described with reference to figures 1 to 5 of the drawings.

11) A system substantially as hereinbefore described with reference to figures 1 to 5 of the drawings.

The Patent Office

INVESTOR IN PEOPLE

Application No:	GB 0031866.7	**Examiner:**	Steven Gross
Claims searched:	1-11	**Date of search:**	13 November 2001

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.S): G4A (AUA)

Int Cl (Ed.7): G06F17/60, E21B47/00, 49/00

Other: Online: EPODOC, WPI, PAJ

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X, E	WO 01/46673 A1	(3PM LLC) See whole document	1-9
A	WO 94/25732 A1	(MAERSK) See whole document	
A	US 4821564 A	(PEARSON) See whole document	
A	FR 2723141 A	(ELF) See whole document	

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